WORLD COFFEE EVENTS

PROCEDURE FOR THE MEASUREMENT OF BREWING WATER TEMPERATURE IN ESPRESSO COFFEE MACHINES

2017

Contents

WCE Procedure for the Measurement of Brewing Water Temperature in Espresso Coffee Machines

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Introduction

The following test procedure shall be followed for quantitative temperature testing of candidate espresso machines under consideration for use within the system of world, national, and regional competitions. This document presents a rigorous procedure with supporting technical justification, for obtaining meaningful brewing temperature measurements for machine comparison, and improvement.

1. Measurement Location

1.1 Specification

The temperature of the brew water shall be measured within the volume below the housing that supports the portafilter, e.g. the brew head, and immediately above the packed bed of coffee, or coffee cake. The location of the temperature probe shall be off center, approximately 1/3 of the distance from the center of the volume to the inner edge of the filter basket. During measurement, the sensing portion of the probe shall only contact water.

1.2 Technical Rationale

This measurement location is chosen for its relevance to the brew process, likely similarity of boundary conditions over a wide range of machine makes, and ease of measurement

3. Measurement Equipment

3.1 Introduction

A fast-responding, electronic temperature probe, positioned as described above, senses the temperature of the water. The probe is mounted in a modified portafilter and filter basket, so that the probe may be conveniently inserted in different machines. For ease of use, measurement consistency, and to ensure that the probe contacts only water, the coffee cake is replaced by a proxy cake. The flow rate of pressurized water through the portafilter is established by a valve, or another metering device. The temperature data is read using a suitable readout device, or a data logger. The requirements of these items will now be discussed in detail. An example of the intended measurement system is depicted in Figures 1-3.

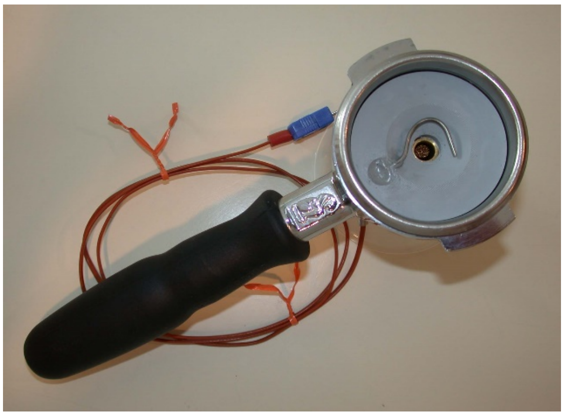

Figure 1. **Portafilter thermometer top view, showing the type-T thermocouple probe and the coffee cake facsimile.**

Figure 2. Portafilter thermometer side view showing the thermocouple probe's exit through the bottom of the portafilter, and the brew water metering orifice.

Figure 3. Installed portafilter thermometer measuring the temperature of the metered brew water stream.

3.2 Temperature Sensor

3.2.1 Specification

The sensor shall be a type-T thermocouple probe, with a response time of less than 0.25 seconds in water.

3.2.2 Technical Rationale

Thermocouple probes are preferred over other sensor types because they are economical, rugged, fast-responding, and not subject to calibration drift at temperatures expected for espresso production. The type-T thermocouple is especially suited for measuring brew water temperature. After 1.5 seconds have elapsed, a temperature probe with a response time of 0.25 seconds will indicate 99.75% of an instantaneous temperature change. For a jump of 50˚ C, this corresponds to a response of 49.9˚ C.

3.3 Probe Installation

3.3.1 Specification

The probe shall be permanently installed in a filter basket, which shall be fitted to an appropriate portafilter for the machine under test. The sensor sheath shall be thermally anchored to the filter basket to minimize heat conduction down the sheath of the probe into the room environment. The portafilter may be modified so that the bottom of the filter basket is open to the room (so-called “bottomless” or “naked” portafilter).

3.4 Simulation of the Coffee Cake

3.4.1 Specification

The volume of the filter basket normally filled by the coffee cake shall be filled with a proxy cake having a thermal conductivity of less than 0.5 Watts/meter Kelvin (W/mK). The volume of the proxy cake should be approximately the same volume as a coffee cake, but may contain deviations from the actual shape of the coffee cake in order to accommodate the temperature probe, metering valves, etc. The distance between the group dispersion screen and the top of the proxy cake (headspace) should approximate the headspace in the presence of an actual coffee cake.

3.4.2 Technical Rationale

A reasonable substitute for the coffee cake enhances practicality.

3.5 Water Flow Rate Adjustment

3.5.1 Specification

A water flow regulator, positioned downstream of the thermometer probe, shall simulate the flow resistance of the coffee cake and provide flow rate regulation as specified in Section 4.3.

3.6 Data Acquisition

3.6.1 Specification

A thermocouple readout device shall measure the voltage generated by the thermocouple probe. Permissible readout devices include electronic thermometers that automatically calculate temperature, or meters such as digital multimeters, provided that a suitable thermocouple reference junction is employed. The preferred method of recording the data is by data logger and computer. Data taken automatically should be acquired at a rate of at least one reading per second.

4 Preparation for Testing

4.1 Machine Cleanliness

4.1.1 Specification

The group(s) shall be back flushed prior to performing the tests. If the dispersion screen(s) is removable for servicing, then it shall be removed, cleaned, and reinstalled. After backflushing, the machine shall remain idle until it has again reached thermal equilibrium as specified in section 4.2.

4.1.2 Technical Rationale

Cleaning the groups minimizes the chance that stray coffee grinds will clog the flow orifice, affecting the volume flow rate during the measurements. Thermal soaking in the idle state is required after backflushing to help insure that the machine is at operating temperature and completely idle prior to the start of testing.

4.2 Espresso Machine Thermal Equilibration

4.2.1 Specification

The espresso machine to be tested shall be at its normal operating temperature for 1 hour prior to testing (the warm-up period). The portafilter containing the thermometer shall be inserted into the group during the warm-up period.

4.2.2 Technical Rationale

In order to simulate real world conditions and good practice, the machine and portafilter must be hot.

4.3 Adjustment of Brew Water Flow Rate

4.3.1 Specification

The flowrate of water through the measurement portafilter shall be measured by weight and shall be adjusted so that 52 grams of water is collected in an elapsed time of 25 seconds $\pm$ 3 seconds.

4.3.2 Technical Rationale

The ratio of brewed beverage weight to weight of dry coffee in WCE competitions currently ranges from 1 : 1 to 2.2 : 1. Assuming that 20 grams of dry coffee are used and that coffee absorbs approximately its weight in water, the 52 gram value falls in the middle of the range of brew ratios commonly used in WCE competitions.

4.4 Steaming Performance

4.4.1 Specification

If the desired brew water testing includes testing of steam performance, the elapsed time required to steam 300 cc (10 ounces) of milk shall be measured. A normal dial-type frothing thermometer shall be immersed in the milk-filled steaming pitcher. Steaming shall continue until the temperature reaches 60 ˚C (140 ˚F).

5 Testing

5.1 Introduction

The test procedure measures brew water temperature at gradually increasing frequency, obtaining temperature data over a variety of duty cycles. By slowly decreasing the interval between measurement sets, the influence of duty cycle on various espresso machine designs may be studied. The measurements may be performed with or without steaming, depending on the purpose of the test. The long idling period of ten minutes prior to the first test run should minimize any effects of pre-test equipment setup.

5.2 Test Procedure

5.2.1 Specification

These steps shall be followed for each of the 14 test points described in 5.3. A single, uniquely identified test portafilter shall be used for each group of a multi-group machine being tested, for all 14 test points.

A) Simulated Idle Period: The machine shall remain idle with the test portafilter installed into the group for the prescribed period of time between measurements.

B) Simulated Disposal of Coffee Cake, Dosing and Tamping: The portafilter shall be removed from the machine, drained of excess water (inversion is sufficient), then reinserted into the group 25 seconds after removal. The group flush shall be incorporated within this time window

C) Group flush: Per 16.3.1 of the 2010 WBC Rules and Regulations, the required group flush may occur either at the removal of the portafilter from the group, or immediately before reinsertion. Since either workflow option is likely to be encountered in competition, either option is permissible during these measurements. However, the order of workflow is to be consistent throughout the measurement series. The manufacturer of a candidate machine being evaluated may specify a preference with respect to the position of the flush within the workflow. Regardless of position, the flush shall be no longer than 2 seconds.

D) Temperature Measurement of Simulated Brewing: Measurement shall commence upon reinstallation of the portafilter. The brew process shall be activated either manually or automatically, in the manner appropriate to the machine. Measurements shall be observed and recorded over an approximate time interval of 25 seconds.

E) Data Recording: During the simulation, the temperature shall be observed and recorded manually, or by computer and data logger (preferred method).

5.2.2 Rationale

Steps A through E mimic expected workflow in the WCE competitions.

5.3 Testing Pattern

5.3.1 Specification

The length of the idle interval for item A of the Test Procedure shall be:

Test Point	Idle Interval (mm:ss)
1	10:00
2	5:00
3	2:00
4	1:00
5	1:00
6	0:30
7	0:30
8	0:10
9	0:10
10	0:10
11	0:10
12	0:10
13	0:10
14	0:10

5.4 Number of Groups to be Tested

5.4.1 Specification

Individual or multiple groups may be tested. Multiple groups may be tested in any combination and portafilter insertion order, including nominally simultaneous insertion.

5.5 Test Procedure Including Effects of Steaming Milk

5.5.1 Specification

The test procedure may be performed with the inclusion of simulated steaming. If this is desired, then the steam valve shall be opened in Step C of the procedure, after initiating brewing. The steam tip shall be immersed in water and opened for the amount of time determined in Section 4.4.

5.6 Temperature Adjustment Response Time Testing

5.6.1 Specification

The time response of espresso machines to step changes in temperature set point may be tested, to determine if temperature equilibrium can be achieved within a sufficiently short time window to enable brewing temperature adjustment per competitor specification during the setup phase of competition. A temperature set point change of 2 °C shall be initiated by either the testing personnel or the manufacturer's representative. After 10 minutes have elapsed, test points 9 through 14 from the test pattern in 5.3 shall be performed. The manufacturer may specify and perform group flushing during the 10-minute window that enhances the response time of the machine. Multiple groups may be tested per 5.4.

6 Interpretation of the Results

Espresso machines selected for use in the WBC, national and regional competitions must meet acceptable performance standards outlined in this section. The method of data analysis and minimum performance criteria are stated below.

6.1 Identification

6.1.1 Specification

The manufacturer, model and serial numbers, number of groups, and the date of the test shall be recorded. Specific operating conditions shall be noted, e.g. one or more groups in operation, with or without steaming, etc. Other pertinent identifying remarks, such as boiler configuration (dual boiler, heat exchanger), or group type should be noted.

6.2 Average Brew Temperature of a Brew Cycle

6.2.1 Specification

The average brew temperature shall be expressed in one of two ways, depending on whether the data is collected manually or automatically by data logger. In the case of manual data collection, the average brew temperature shall be the temperature observed most often during a specific simulated brew cycle, ignoring temperature observations during the first three seconds of the cycle. Ignoring results during the first three seconds negates the effect of thermometer lag on the result. For automatic data collection, the average brew temperature shall be the average of all temperature readings during the brew cycle except for those occurring in the first three seconds.

6.3 Brew Temperature Reproducibility (Individual Group)

6.3.1 Specification

The brew temperature reproducibility is the ability of an espresso machine to produce brewing water at the same average temperature over a variety of use conditions. This information may be calculated from manually collected or computer collected data. The brew temperature reproducibility shall be twice the standard deviation of all 14 average brew temperatures obtained in the test series. Average brew temperature is defined in 6.2.

6.3.2 Calculating Standard Deviation

Standard deviation is defined as:

$$s = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \overline{y})^2}{n-1}}$$

where y_i is the value of a single temperature observation (per 6.2), $\overline{y}$ is the average of the 14 brew temperatures obtained in the test pattern described in 5.3, and *n* refers to the total number of observations (in our case n = 14). The standard deviation may be easily calculated using functions in common spreadsheet programs. The STDEV function in Microsoft Excel is an example of such a function.

6.4 Inter Group Temperature Consistency

6.4.1 Specification

Inter-group temperature consistency is defined as the ability of all groups to provide the same brewing temperature. This value is obtained as follows:

i. Calculate averages of the 14 average brew temperatures obtained per 6.2 in each test series performed per 5.3.
ii. Inter-group temperature consistency shall be the difference between the lowest and highest value obtained in step 1.

6.5 Minimum Performance Criteria

6.5.1 Specification

Espresso machines suitable for competition must supply an average brew temperature as defined in 6.2 of between 90.5 and 96 ºC (195 to 205 ºF) per the WBC Rules and Regulations, with a maximum individual group brew temperature reproducibility (per 6.3) of 1.1 °C (2.0 °F).

The maximum allowable inter-group temperature consistency value is 1.1 °C (2.0 °F).

Response to temperature set point step changes (5.6) will be assessed qualitatively for achievement of equilibrium within the time window in 5.6, ease of adjustment, and the level of attention required in order to quickly achieve equilibrium.

6.6 Espresso Machine Temperature Profile Reproducibility

6.6.1 Specification

The measurement procedure is neutral on the question of optimum brew temperature profile, defined as the time-dependent deviation from the average brew temperature during the course of a brew cycle. Regardless of the profile, the espresso machine should be able to reproduce the profile under a variety of duty cycles. The profile may be evaluated graphically, and profile reproducibility may be considered qualitatively under 6.6.

6.7 Qualitative Comments

6.7.1 Specification

Qualitative impressions may be noted in the results.

6.8 Validity of the Results

Calculations of averages and standard deviations are easily accomplished using a variety of computer spreadsheets. The average temperature value and the method of calculating temperature stability use commonly applied methods.

References

1. *Manual on the Use of Thermocouples in Temperature Measurement,* ASTM Special Publication 470A, Omega Press, Stamford, Connecticut 06907, 1983.